

[0001]                   SIMPLE BLOCK SPACE TIME TRANSMIT  
DIVERSITY USING MULTIPLE SPREADING CODES

[0002]                   Cross Reference to Related Applications

[0003]           This application is a continuation of Application No. 09/999,287, filed on November 15, 2001; which claims priority from Provisional Application No. 60/254,013, filed on December 7, 2000, all of which are incorporated herein by reference.

[0004]                   BACKGROUND

[0005]           The present invention relates to communications systems imploring code division multiple access (CDMA) techniques. More particularly, the present invention relates to a transmission diversity scheme which can be applied to a CDMA communication system.

[0006]           Spacial diversity has been proposed for support of very high data rate users within third generation wide band code division multiple access systems such as CDMA. Using multiple antennas, the systems achieve better gains and link quality, which results in increased system capacity. Classically, diversity has been exploited through the use of either beam steering or through diversity combining.

[0007]           More recently, it has been realized that coordinated use of diversity can be achieved through the use of space-time codes. Such systems can theoretically increase capacity by up to a factor equaling the number of transmit and receive antennas in the array. Space-time block codes operate on a block of input symbols producing a matrix output over antennas and time.

[0008]           In the past, space-time transmit diversity systems have transmitted consecutive symbols simultaneously with their complex conjugates. This type of system, though may result in symbol overlap at the receiving end, with the amount of overlap being dependent on

the length of the impulse response of the propagation channel. In time division duplex (TDD) mode, this symbol overlap will have to be accounted for in the joint detection receiver. The joint detector will have to estimate the transmitted symbols and their conjugates, resulting in an increase in complexity of the joint detection.

[0009] In order to alleviate this increase in joint detection, systems have been created which transmit two similar but different data fields. The first data field, having a first portion,  $D_1$ , and a second portion,  $D_2$ , is transmitted by the first antenna. A second data field is produced by modifying the first data field. The negation of the conjugate of  $D_2$ ,  $-D_2^*$ , is the first portion of the second data field and the conjugate of  $D_1$ ,  $D_1^*$ , is the second portion. The second data field is simultaneously transmitted by the second antenna. This type of system results in the joint detection implemented at the receiver needing only to estimate the same amount of symbols as in the case of a single transmit antenna. A block diagram of this system is illustrated in Figure 1.

[0010] Although the above system reduces the complexity of joint detection for a single data block, joint detection requires the use of two joint detectors at the receiver in a system employing two transmit diversity antennas. Each joint detection device estimates the data from one of the antennas. The estimated data is combined to produce the original data. Therefore, the receiver in such a system has a high complexity resulting in higher receiver expense.

[0011] Accordingly, there exists a need for a transmit diversity system requiring less complexity and receiver expense.

## [0012] SUMMARY

[0013] The present invention is a method and apparatus for a base station to transmit a data field of symbols. A first data field of symbols is generated and encoded to produce a second data field having complex conjugates of the symbols of the data field. The first and second data fields are then spread, wherein the first data field is spread using a first

channelization code and the second data field is spread using a second channelization code. Each of the channelization codes are uniquely associated with one of a first and second antenna. An RF signal including the first and second spread data fields is then transmitted over a first and second antenna.

[00014] BRIEF DESCRIPTION OF THE DRAWINGS

[00015] Figure 1 is a block diagram of a prior art communication system employing space-time transmit diversity.

[00016] Figure 2 is a block diagram of a transmitter and receiver in a communication system in accordance with the preferred embodiment of the present invention.

[00017] Figure 3 is a flow diagram of the transmit diversity system of the present invention.

[00018] Figure 4 is a graph of the performance of the transmit diversity system of the present invention.

[00019] Figure 5 is a block diagram of a transmitter and receiver in a communication system in accordance with an alternative embodiment of the present invention.

[00020] Figure 6 is a flow diagram of an alternative transmit diversity system of the present invention.

[00021] DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[00022] Figure 2 is a block diagram of a transmitter 10, preferably located at a base station, and a receiver 20, preferably located at a user equipment (UE), in a CDMA communication system in accordance with the preferred embodiment of the present invention. Although it is preferable to have the transmitter located at a base station and the receiver located at the UE, the receiver and transmitter may switch locations and the present invention operate on an uplink communication. The transmitter 10 comprises a block encoder 11, a plurality of channelization devices 8, 9, a plurality of spreading sequence

insertion devices 12, 13, and a plurality of antennas 15, 16. Although Figure 1 illustrates a transmitter comprising two (2) antennas, it should be apparent to those having skill in the art that more than two (2) antennas may be used, such as N antennas.

[00023] A typical communication burst has two data fields separated by a midamble sequence. Preferably, the same encoding procedure, as discussed in the following, for one data field is also performed on the other data field. Data to be transmitted by the transmitter 10 is produced by a data generator (not shown). The resulting data symbols ( $S_1, S_2, \dots, S_{N/2}$ ), ( $S_{N/2+1}, S_{N/2+2}, \dots, S_N$ ) of the first data field, which can be represented by sub-data fields  $D_1$  and  $D_2$ , are input into the block encoder 11, preferably a block space-time transmit diversity (BSTTD) encoder. The block encoder 11 encodes the input symbols and generates the complex conjugate of  $D_1$  and the negation of the conjugate of  $D_2$ :  $D_1^*$ ,  $-D_2^*$ . The encoder 11 also changes the order of the symbols so that  $-D_2^*$  is ahead of  $D_1^*$ . Preferably, an analogous encoding of the second data field is also performed.

[00024] In accordance with the preferred embodiment of the present invention, the data fields,  $D_1, D_2$  and  $-D_2^*, D_1^*$  are forwarded to a first and second channelization device 8, 9, respectively. The first channelization device 8 spreads the data blocks  $D_1, D_2$  by a first channelization code, and  $-D_2^*, D_1^*$  by the second channelization device 9 using a second different channelization code. Each of the spread data blocks from the first and second channelization devices 8, 9 are then scrambled by the scrambling code associated with the transmitter 10.

[00025] Once the symbols  $D_1, D_2, -D_2^*, D_1^*$  have been scrambled, they are mixed with a first and second midamble through training sequence insertion devices 12, 13, producing two communication bursts 17, 18. The two bursts 17, 18 are modulated and simultaneously transmitted to the receiver 20 over antenna 15 and diversity antenna 16, respectively.

[00026] The receiver 20 comprises a joint detection device (JD) 24, a BSTTD decoder 22, a channel estimation device 23 and an antenna 26. The antenna 26 of the UE receives

various RF signals including the communication bursts 17, 18 from the transmitter 10. The RF signals are then demodulated to produce a baseband signal.

[00027] The baseband signal is then forwarded to the joint detection device 24 and the channel estimation device 23. As those skilled in the art know, the channel estimation device 23 provides channel information, such as channel impulse responses, to the joint detection device 24.

[00028] The joint detection device 24, coupled to the channel estimation device 23 and BSTTD decoder 22, utilizes the channel information and the channelization codes to detect the soft data symbols  $d_1$ ,  $d_2$ ,  $-d_2^*$ ,  $d_1^*$  in the received signal. The channel impulse response for each burst is determined using that burst's midamble sequence. Since each burst was transmitted using a different spreading code, the joint detection device 24 treats each burst as being transmitted by a different user. As a result, any joint detection device which can recover data from different transmitter sites may be used. Such joint detection devices include zero forcing block linear equalizers, detection devices using Cholesky or approximate Cholesky decomposition, as well as many others. The joint detection device 24 estimates the data symbols of each of the bursts 17, 18 output by the transmitter antennas 15, 16 and forwards the estimates to the BSTTD decoder 22.

[00029] The BSTTD decoder 22, coupled to the joint detection device 24, receives the estimated soft data symbols  $d_1$ ,  $d_2$  and  $-d_2^*$ ,  $d_1^*$  corresponding to the antennas 15, 16 and decodes the symbols to yield a single data field's soft symbols,  $d_{STTD}$ .

[00030] The flow diagram of the present invention is illustrated in Figure 3. A data generator generates data to be transmitted to the receiver 20 (step 301). Each data field is separated into two sub-data fields  $D_1$ ,  $D_2$  (step 302). The sub-data fields  $D_1$ ,  $D_2$  are forwarded to the block encoder 11 and the first channelization device 8 (step 303). The sub-data fields forwarded to the block encoder 11 are encoded (step 304) and forwarded to the second channelization device 9 (step 305). Each channelization device 8, 9 spreads their respective data input using a separate channelization code associated with a respective

antenna 15, 16 (step 306). The two spread signals are then scrambled, using the scrambling code associated with the base station (step 307) and transmitted to the receiver 20 over diversity antennas 15, 16 (step 308).

[00031] The receiver 20 receives a RF communication signal including the two spread signals from the diversity antennas 15, 16 (step 309), demodulates the signal and forwards the demodulated signal to the channel estimation device 23 and joint detection device 24 (step 310). The received signal is processed by the channel estimation device 23 (step 311) and the channel information applied by the joint detection device 24 along with the channelization codes, to estimate the transmit symbols from the diversity antennas 15, 16 (step 312). The detected sub-data fields, corresponding to each diversity antenna 15, 16, are forwarded to the BSTTD decoder (step 313), which decodes the soft symbol sub-fields to yield a single data field's soft symbols, dSTTD (step 314).

[00032] Similar to the preferred embodiment disclosed above, Figure 5 is a block diagram of an alternative transmitter 40, preferably located at a base station, and a receiver 50, preferably located a user equipment (UE) in a communication system. The transmitter 40 comprises a plurality of channelization devices 48, 49, a plurality of spreading sequence insertion devices 42, 43, and a plurality of antennas 45, 46.

[00033] Data to be transmitted by the transmitter 40 is produced by a data generator (not shown). The resulting data symbols ( $S_1, S_2, \dots, S_{N/2}$ ), ( $S_{N/2+1}, S_{N/2+2}, \dots, S_N$ ) of the first data field, which can be represented by sub-data fields  $D_1$  and  $D_2$ , are input to a first and second channelization device 48, 49, respectively. The first channelization device 8 spreads the data blocks  $D_1, D_2$  by a first channelization code, and the second channelization device 49 spreads the data blocks  $D_1, D_2$  by a second different channelization code. Each of the spread data blocks from the first and second channelization devices 48, 49 are scrambled by the scrambling code associated with the transmitter 40.

[00034] Once the symbols have been scrambled, they are mixed with a first and second midamble through training sequence insertion devices 42, 43, producing two communication

bursts 44, 45. The two bursts 44, 45 are modulated and simultaneously transmitted to the receiver 50 over antenna 46 and diversity antenna 47, respectively.

[00035] The receiver 50 comprises a joint detection device (JD) 54, a decoder 22, a channel estimation device 53 and an antenna 51. The antenna 51 of the UE receives various RF signals including the communication bursts 44, 45 from the transmitter 40. The RF signals are then demodulated to produce a baseband signal.

[00036] The baseband signal is then forwarded to the joint detection device 54 and the channel estimation device 53. The joint detection device 54, coupled to the channel estimation device 53 and decoder 52, utilizes the channel information and the channelization codes to detect the soft data symbols  $d_1$ ,  $d_2$ , in the received signal. The channel impulse response for each burst is determined using that burst's midamble sequence. Since each burst was transmitted using a different spreading code, the joint detection device 54 treats each burst as being transmitted by a different user. The joint detection device 54 estimates the data symbols of each of the signals 44, 45 output by the transmitter antennas 46, 47 and forwards the estimates to the decoder 52.

[00037] The decoder 52, coupled to the joint detection device 54, receives the estimated soft data symbols  $d_1$ ,  $d_2$  corresponding to the antennas 46, 47 and decodes the symbols to yield a single data field's soft symbols,  $d$ .

[00038] The flow diagram of the alternative embodiment is illustrated in Figure 6. A data generator generates data to be transmitted to the receiver 40 (step 601). Each data field is separated into two sub-data fields  $D_1$ ,  $D_2$  (step 602). The sub-data fields  $D_1$ ,  $D_2$  are forwarded to the first channelization device 48 and to the second channelization device 49 (step 603). Each channelization device 48, 49 spreads their respective data input using a separate channelization code associated with each antenna 46, 47 (step 604). The two spread signals are then scrambled, using the scrambling code associated with the base station (step 605) and transmitted to the receiver 50 over diversity antennas 46, 47 (step 606).

[00039] The receiver 50 receives a RF communication signal including the two spread signals from the diversity antennas 46, 47 (step 607), demodulates the signal and forwards the demodulated signal to the channel estimation device 53 and joint detection device 54 (step 608). The received signal is processed by the channel estimation device 53 (step 609) and the channel information applied by the joint detection device 54 along with the channelization codes, to estimate the transmit symbols from the diversity antennas 46, 47 (step 610). The detected sub-data fields, corresponding to each diversity antenna 46, 47, are forwarded to the decoder 52 (step 611), which decodes the soft symbol sub-fields to yield a single data field's soft symbols,  $d_{STTD}$  (step 612).

[00040] By using additional channelization codes, the above approaches can be applied to an antenna array having any number of antennas. Each antenna has its own associated channelization code and midamble. If a block encoder is used, the data field transmitted by each of the antennas has a unique encoding, allowing the use of a single joint detector at the receiver.

[00041] The BSTTD transmitter with two channelization codes of the present invention allows for the use of a cheaper and simpler method of transmit diversity. The use of different channelization codes per transmit antenna requires only one joint detection device at the receiver resulting in a less complex receiver system than those of the prior art. Figure 4 is a graph showing the raw BER of various block STTD decoders. The model is based on all the receivers using a block linear equalizer (BLE) based approach to JD. NTD means the single antenna case, i.e., no transmit diversity. STTD with 1 code is the traditional block STTD JD. STTD with 2 code is the disclosed block STTD transmitter. Simple STTD with 2 code is the transmission system disclosed in the alternative embodiment. As illustrated, the benefit of 2 codes for STTD can be summarized as follows: 1) there is up to a 0.5 dB gain at 0.01 raw Bit error rate over 1 code STTD; and 2) by eliminating the encoding block in simple STTD with 2 code, the performance degradation is only 0.2 dB at 0.1 raw BER and no degradation



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at 0.01 raw BER. The performance improvement over NTD is still 1.0 dB and 2.7 dB at 0.1 and 0.01 raw BER.

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